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A Perspective of Joint Agency Collaboration on Fischer-Tropsch Fuels (2003-2005)

Federal Laboratory Consortium 2008 Midwest Regional Conference, St. Louis

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- **DoD-DOE coordinated study of Fischer-Tropsch fuels**
  - Under the Flexible JP-8 Pilot Plant Program (2003-2005)
    - FY02, FY04, FY05 funding (congressional)
    - Syntroleum Corp. (prime contractor)
  - Managed by Tank Automotive Research, Development and Engineering Center (TARDEC-National Automotive Center)
    - Office of Secretary of Defense (OSD) oversight

Photo courtesy of Syntroleum Corp.

- **Catoosa Demonstration Facility (Syntroleum FT Plant)**
  - Co-funded by DOE
    - Ultra-CleanTransportation Fuels Demonstration Program
  - Produced jet/diesel fuels from natural gas
    - Fuel source for DoD, DOE, DOT RDT&E projects
  - Achieved demonstration goals, shutdown in 2006

Research Participants

- **Air Force**
  - **Air Force Research Laboratory, Propulsion Directorate**
    - University of Dayton Research Institute
- Army
  - **Tank Automotive Research, Development and Engineering Center, Fuels & Lubricants Laboratory**
    - TARDEC Fuels and Lubricants Research Facility, Southwest Research Institute
- **Navy**
  - **Naval Air Systems Command, Fuels & Lubricants Division Laboratory**
- **DOE**
  - **National Energy Technology Laboratory**
- **Syntroleum Corporation**

Memorandum of Agreement (MOA) Among Federal Labs (3-DoD, 1-DOE)

- **Established purpose**
  - Collaborative R&D of alternative fuels, especially synthetic fuel produced from Fischer-Tropsch (FT) technology and JP-8 Flexible JP-8 Pilot Plant Program
- **Established a goal**
  - Develop synthetic fuel spec for all JP-8/JP-5 fueled equipment
- **Defined forms of collaborative activities**
  - Exchange program plans information
  - Consultations by senior policy/program officials for joint planning/program execution
  - Routine exchange of current scientific and technical information, including results and methodologies of ongoing relevant RDT&E activities
  - Conducting seminars, symposia, other scientific/technical meetings for agreed upon topics
  - Joint or individual Party publications, papers, reports, etc.
  - Site visits to locations where work of mutual interest is being performed
  - Joint projects to share the analysis, research, and costs

- **Intended benefits**
  - More efficient resource utilization and capitalization
  - Avert duplication
  - More advanced technology development

"Leveraging Opportunities to Fill Technology Gaps."

Scope of MOA

- **Topics**
  - Research and development of alternative FT technology
  - Research and development of sealing materials compatibility with synthetic fuel specification (JP-8/JP-5 type fuel)
  - Evaluation of synthetic fuel
  - Component, system, and/or fuel certification and testing
  - Emission tests
  - Lubricity evaluations
  - Development of a synthetic fuel specification
- **Key arrangements**
  - Performance by third parties allowed (government, industry, academic, or non-profit institutions)
  - TARDEC responsible for overall management and reporting to OSD
  - Coordinated synthetic fuel specification development with Coordinating Research Council (CRC) Aviation Committee – key aviation industry stakeholder group influencing commercial jet fuel spec (ASTM D1655)

Coordination with industry established as a tenet of the Flexible JP-8 Pilot Plant Program (outside of the MOA).

Initial R&D Responsibilities of Participating Labs

- **DOE – NETL**
  - In-depth chemical analysis of synthetic and conventional fuels
  - Analysis of lubricity-enhancing components of petroleum-derived fuels
  - Molecular modeling and experimental studies of elastomer-aromatic systems
  - Ab initio energetic calculations of fuel-elastomer molecule combinations
- **DoD – Army**
  - Compatibility (of synthetic fuel) with Army equipment, incl. fuel storage, distr., and handling
  - Elastomer (seal) compatibility study
  - Lubricity testing (bench-top and components)
  - Exhaust emissions testing and fuel economy effects (compression ignition engine)
- **DoD – Air Force**
  - Compatibility with aviation equipment, including thermal stability
  - Exhaust emissions testing (aviation turbine engine)
  - Compatibiity with elastomer materials (incl. sealants and coatings)
  - Research of non-aromatic compounds impacting elastomers, such as high molecular weight alcohols
- **DoD – Navy**
  - Compatibility of synthetic fuel with Navy equipment, including long-term storage
  - Additive requirements
  - Lubricity evaluations

"Leveraging Opportunities to Fill Technology Gaps."

Published Papers of Joint Agency Collaboration on Synthetic Fuel

Partial list

American Chemical Society	
2003	Ab Initio Study of Interaction of a Model Nitrile Polymer with Various Model Fuel Molecules" (R.A. Glenn Award Nomination)
2004	Production and Characterization of Synthetic Jet Fuel Produced from Fischer-Tropsch Hydrocarbons Composition of Syntroleum S-5 and Conformance to JP-5 Specification Evaluation of Fischer-Tropsch Synthetic Fuels for United States Naval Applications Separation and Identification of Oxygenates as Suspected Performance-Enhancers for Synthetic Jet Fuels The Swelling of Selected O-ring Materials in Jet Propulsion and Fischer-Tropsch Fuels
2005	Reduction of Turbine Engine Particulate Emissions Using Synthetic Jet Fuel Effects of Aromatic Jet Fuel Concentration on the Emissions of a T63 Engine
Society of Automotive Engineers	
2004	Alternative Fuels: Assessment of Fischer-Tropsch Fuel for Military Use in 6.5L Diesel Engine (SAE Transactions selection)
2005	Fischer-Tropsch Fuels: Why Are They of Interest to the United States Military? Bench-top Lubricity Evaluator Correlation with Military Rotary Fuel Injection Pump Test Rig
2006	Properties of Fischer-Tropsch (FT) Blends for Use in Military Equipment (SAE Transactions selection)
American Institute of Aeronautics and Astronautics	
2004	Fischer-Tropsch Jet Fuels – Characterization for Advanced Aerospace Applications
Energy & Fuels 2005	
2005	Extraction, Separation, and Identification of Polar Oxygen Species in Jet Fuel

Jet Fuel Symposium and session on the Chemistry of FT Jet Fuels organized and chaired by DoD

"Leveraging Opportunities to Fill Technology Gaps."

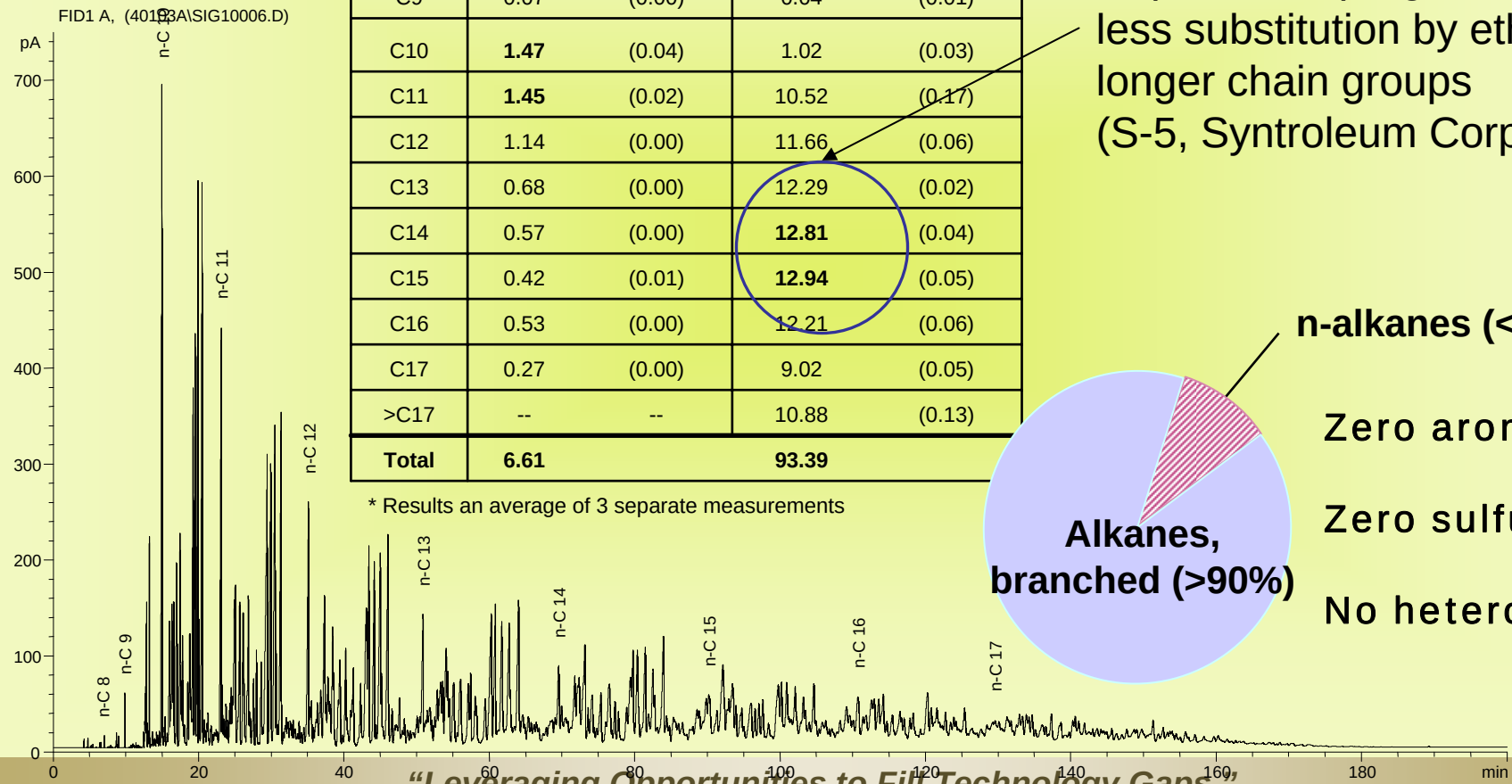
Carbon Characterization & Branching Studies by NETL

	% Abundance* (% Std. Dev.)			
	Normal	*(Std. Dev.)*	*Branched*	*(Std. Dev.)*
<C8	--	--	0.01	(0.00)
C8	0.01	(0.00)	--	--
C9	0.07	(0.00)	0.04	(0.01)
C10	**1.47**	(0.04)	1.02	(0.03)
C11	**1.45**	(0.02)	10.52	(0.17)
C12	1.14	(0.00)	11.66	(0.06)
C13	0.68	(0.00)	12.29	(0.02)
C14	0.57	(0.00)	**12.81**	(0.04)
C15	0.42	(0.01)	**12.94**	(0.05)
C16	0.53	(0.00)	12.21	(0.06)
C17	0.27	(0.00)	9.02	(0.05)
>C17	--	--	10.88	(0.13)
Total	**6.61**		**93.39**	

* Results an average of 3 separate measurements

Data courtesy NETL

Mostly methyl-substitued isoparaffins, progressively less substitution by ethyl+ longer chain groups (S-5, Syntroleum Corp.)



n-alkanes (<10%)

Zero aromatics

Zero sulfur

No heteroatoms

Lubricity Testing by Army

- **Rotary fuel injection pump testing**
  - **Rotary fuel injection pump is fuel-lubricated, used in tactical ground vehicles (High Mobility Multi-Purpose Wheeled Vehicle)**
  - **FT fuel additized with military-approved lubricity improver test results indicative of acceptable performance of fuel pump in field**
  - **Both at min. and max. treat rates per Qualified Products List (QPL-25017)**
  - **Reference: SAE Paper 2004-01-2961**

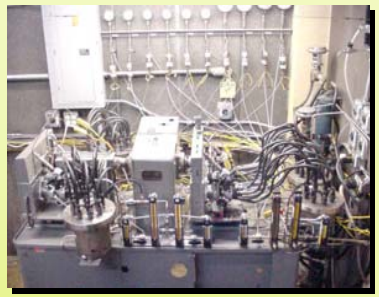


Photo courtesy of TARDEC
F&L Research Facility, SwRI™

Test	Pump	Duration (hours)	Change[1] (mm)	FT Fuel CI/LI (mg/L)
1	1	95.6	0.096	Untreated
	2	150.7	0.068	
2	3	500	0.007	12 (Min.[2])
	4	500	-0.006	
3	5	500	0.005	22.5 (Max.[2])
	6	500	0.002	

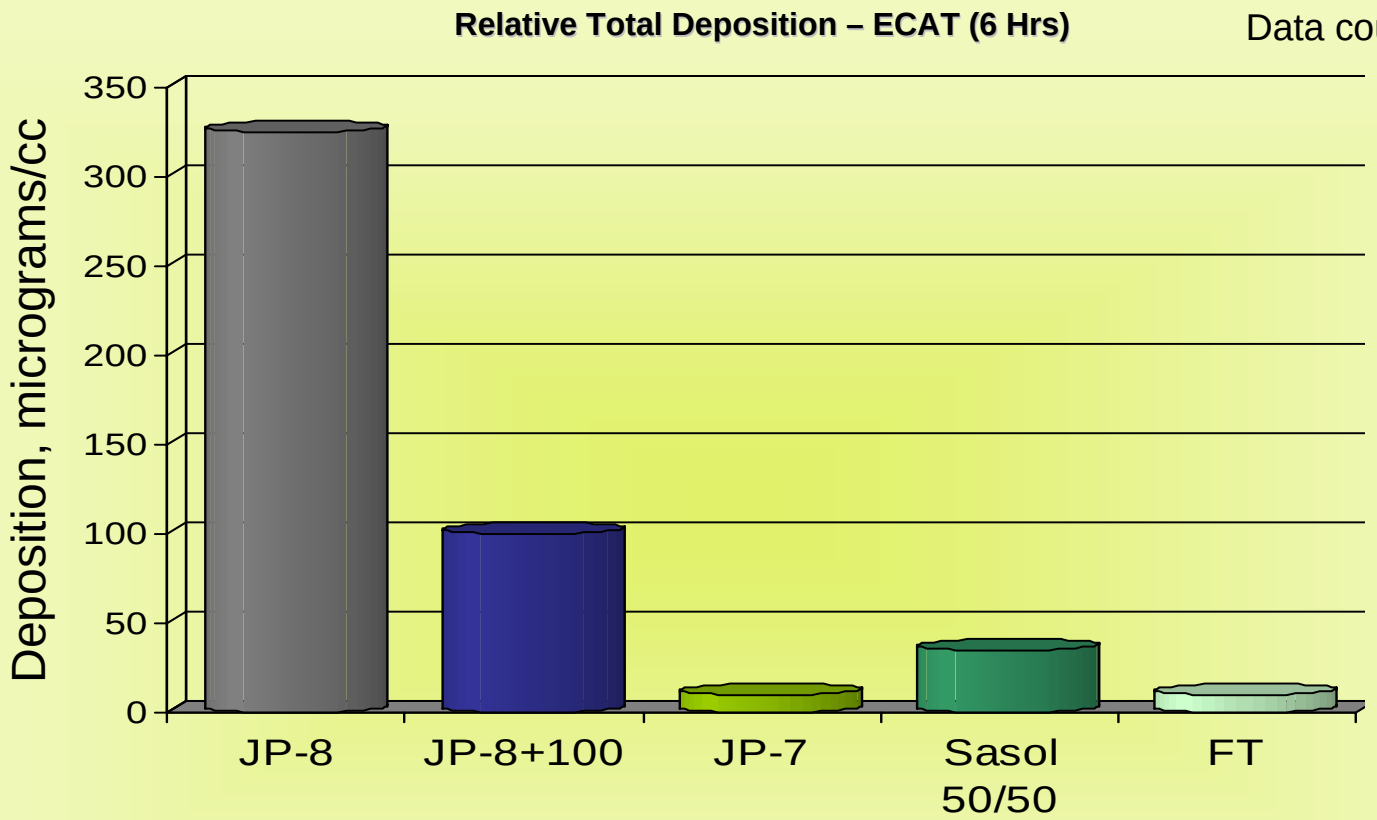
[1] Change in roller-to-roller dimension pre- & post- test.
[2] Min. and Max. treat rates per QPL-25107.

Data courtesy TARDEC F&L Research Facility, SwRI ™

Poor lubricity of FT fuel is improved with standard lubricity improver additive used in petroleum fuel (JP-8/JP-5).

Thermal Stability Testing by Air Force

Data courtesy AFRL



FT fuel has excellent thermal stability as compared to petroleum fuels.

Shipboard Use Evaluation by Navy

Storage Stability Test Results
(Syntroleum S-5)

w/o AO	0 Hr	24Hrs	48Hrs	72Hrs	96Hrs
Saybolt Color	30	29	24	19	22
Peroxide, ppm	0	>240	>240	>240	>240
Gums, mg/100ml	0	0	0.1	1	7.9
20 ppm AO	0 Hr	24Hrs	48Hrs	72Hrs	96Hrs
Saybolt Color	30	30	30	30	30
Peroxide, ppm	0	0	0	0	0
Gums, mg/100ml	0.4	0.3	0.4	0.5	1.3
Antioxidant ppm	22.2	9.5	8.7	7.6	9.1
30 ppm AO	0 Hr	24Hrs	48Hrs	72Hrs	96Hrs
Saybolt Color	30	30	30	30	30
Peroxide, ppm	0	0	0	0	0
Gums, mg/100ml	0.1	0.3	0.3	0.3	0.4
Antioxidant ppm	33.3	33	33.7	33	33.3

Compatibility Evaluation Test Results
(2 FT fuels: F-T 1 and F-T 2)

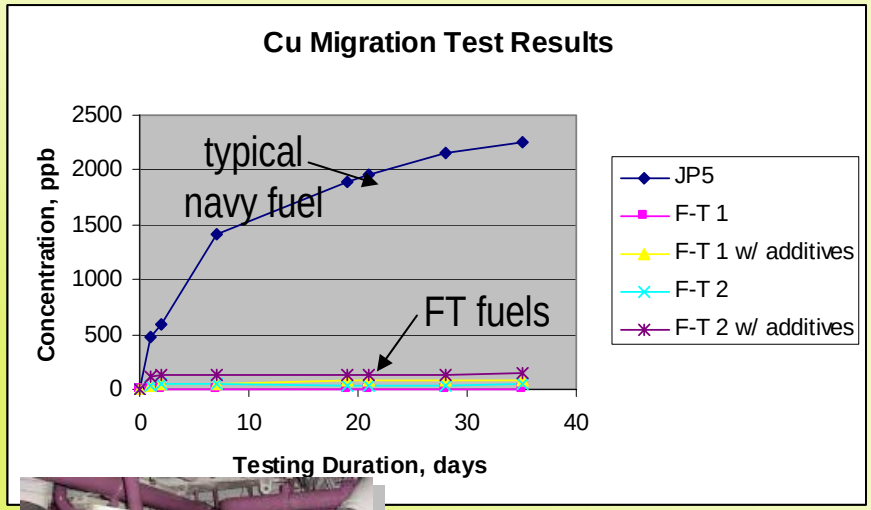


Photo courtesy of NAVAIR F&L Lab

Data courtesy
NAVAIR F&L Lab

FT fuel exhibits excellent long-term storage stability; responds well to standard anti-oxidants used in petroleum fuel (JP-5 / JP-8) and is compatible with Cu-Ni alloy used in shipboard fuel distribution systems

Successful Collaboration of Federal Labs in R&D of Synthetic Jet Fuel

- **Key factors leading to success**
  - **Strong team of Federal lab researchers and partners, augmented by technical expertise of FT fuel provider**
  - **Well-constructed MOA established a purpose and common goal, defined roles and responsibilities of Parties**
  - **Parties implemented all forms collaborative activities defined in MOA**
- **Key achievements**
  - **Early achievements of this collaboration established a cornerstone of the OSD Assured Fuels Initiative launched in late 2004; goals under this initiative are still being pursued today**

Vision

DoD/AT&L intends to catalyze commercial industry to produce clean fuels for the military from secure domestic resources using environmentally sensitive processes as a bridge to the future.

  - **Draft synthetic fuel specification resulting from collaboration issued in 2006; formed basis of recent modification of JP-8 specification to allow blends of FT kerosene and JP-8**